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Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th St., SW
Washington, DC 20554

Re: Authorizing Permissive Use of the "Next Generation" Broadcast Television
Standard, GN Docket No. 16-142

Dear Ms. Dortch,

Please see the enclosed report from Ethertronics, Inc., a leading designer and manufacturer radio frequency components used in a wide variety of wireless devices today. In the report we examine the substantial challenges of incorporating both 600 MHz LTE and ATSC 3.0 technologies in a single device.

In summary, integrating an additional radio for ATSC 3.0 functionality into smartphones will impact LTE radio system performance due to interference between the multiple radio systems and coupling among antennas in the overall antenna system. While larger smartphones will help to mitigate this interference, there are practical limits to the acceptable size of a mobile devices consumers are willing to purchase. Because of this physical limit, there is a zero-sum trade-off between LTE and ATSC 3.0 reception that must be carefully and deliberately considered by manufacturers and operators of LTE networks.

Pursuant to Section 1.1206(b)(2) of the Commission's rules, an electronic copy of this letter is being filed in the above-referenced dockets. Please direct any questions regarding this filing to me.

Sincerely,

/s/ Sebastian Rowson Ph.D.
Chief Scientist
Ethertronics Inc.

Antenna Issues Associated with Integration of Additional Radio Functionality in Smartphones

Integration of additional radio system functionality into smartphones has the potential to cause multiple problems in terms of interference, reduced cellular radio performance, and volume constraints (industrial design). The integration of UHF TV functionality is of specific concern due to the low frequency of operation and lack of internal volume in smartphone assemblies for a stand-alone UHF antenna. These problems along with cost constraints and requirements for high antenna gain for TV reception are reasons why TV viewing usage in handsets in North America and Europe is practically non-existent, at least from a hardware perspective. These problems along with cost constraints and requirements for high antenna gain for TV reception are reasons why TV viewing usage in handsets in North America and Europe is practically non-existent, at least from a hardware perspective and ATSC 3.0 does not change these fundamental challenges.

Background

Current smartphones contain 4 or 5 antennas to service the multiple radios, including a main cellular, secondary cellular, one or two Wi-Fi antennas, and a GPS antenna. This number of antennas in a small volume complicates the antenna system integration effort. A majority of the internal volume of a smartphone is reserved for the battery and display, with the circuit board containing the radio chipsets and the camera competing with the antenna (and speaker) system for the remainder.

Current trends in LTE and Wi-Fi point to an increase in number of antennas due to a move to higher orders of MIMO. High end smartphones now have 2x2 MIMO configurations implemented at Wi-Fi using 802.11ac chipsets. Typical LTE enabled handsets now have 2x2 MIMO antenna configurations for receive at the lower frequency bands (698 to 960 MHz) and up to 4x4 MIMO antenna configurations at the higher frequency bands (1710 to 2700 MHz). This increase in antenna count in smartphones for the existing radios makes it difficult to find available internal volume for new radios and antennas. With internal volume at a premium in today's smartphone it makes sense to accommodate the radio functions (LTE and Wi-Fi) that consumers use for regular data consumption and communication.

Handset with TV reception typically use an external whip antenna . The extended whip provides adequate antenna gain when the user is outdoors for many locations but not all. The negative

aspects of using an external whip is the requirement for internal volume for the antenna in the “stored” position as well as breakage of the antenna when extended. The reduced aesthetics of a handset design with external antenna is also of concern. External whip antennas integrated into handsets can be functional in some countries due to a dense TV transmit tower layout which allow for a strong enough signal reception in the region targeted for coverage. More recent handsets have been taken to market where an internal antenna is integrated for TV reception. The difficulties with this internal approach is three-fold: 1) internal volume must be allocated for this antenna, 2) antenna performance of the internal antenna is reduced compared to an external whip antenna, and 3) the internal TV antenna has the potential to couple to the other antennas in the handset.

Limiting Constraints Imposed by Antenna Theory

As the cellular industry has transitioned from 3G to 4G the frequency bandwidth requirements for the antenna system have substantially increased. The cellular antenna count has also increased due to 4G being a MIMO protocol. Similarly, Wi-Fi antennas integrated into smartphones have increased in bandwidth as the industry transitioned from 2.4 GHz (802.11 b,g) to 2.4 and 5 GHz bands (802.11n,ac). Also, higher orders of MIMO implemented at Wi-Fi has increased antenna count in the smartphone. This increase in the frequency bandwidth along with the additional antennas needed to be integrated into the handset have typically resulted in decreased antenna system efficiency.

Wheeler’s formula can be used to define the volume required to achieve a specific bandwidth for efficient antenna performance. Wheeler’s basic equation for small antennas states:

$$\frac{\Delta f}{f} = K \times \frac{\text{antenna mode volume}}{(\text{radio wavelength})^3}$$

Where f = frequency of operation

Δf = frequency bandwidth

K = a dimensionless factor related to the antenna technology used

Antenna mode volume = volume required for efficient electromagnetic field generation

Wheeler’s formula states that as the bandwidth requirement increases so does the volume required of the antenna. Additionally, we see that as the frequency of operation decreases the volume requirement for the antenna increases. These two concepts are highlighted in figure 1, where lines of constant bandwidth are shown for various frequencies of operation. These lines of constant bandwidth are displayed in a graph where the values along the x-axis define the frequency of operation while the values along the y-axis define the antenna mode volume in cubic centimeters. Figure 1 clearly shows why it is more difficult to integrate low frequency antennas compared to

high frequency antennas in a small device such as a smartphone, and why increasing the bandwidth of an antenna requires more volume for the antenna to occupy or will result in reduced antenna performance. A close look at the graph shows that for frequencies below 600 MHz the antenna mode volume required to support 35 MHz of bandwidth exceeds the 60 cu. cm. that is the volume of today's typical smartphone. An antenna that operates below 600 MHz can still be integrated into the smartphone but the efficiency will be impacted.

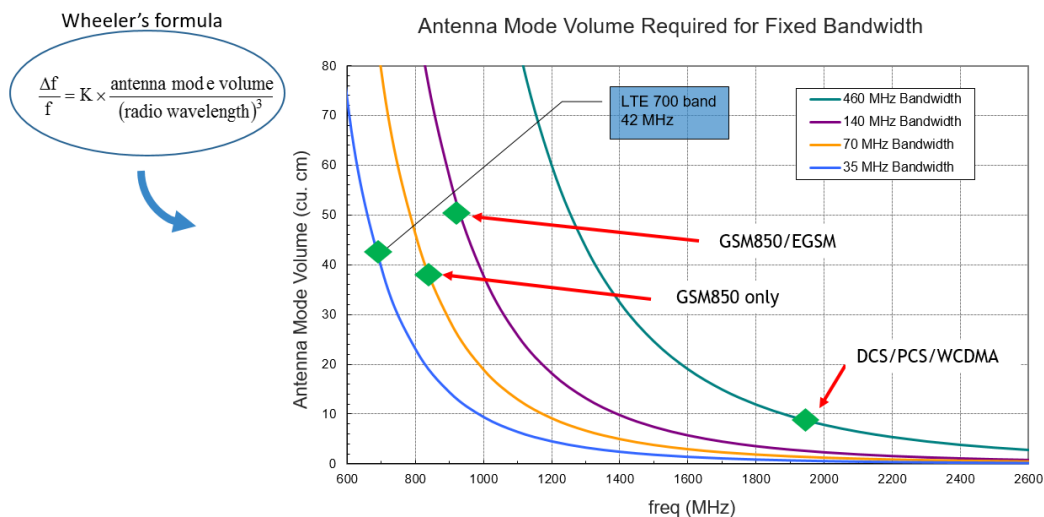


Figure 1. Antenna Mode volume

An FCC study shows the U.S. suffers from weak TV signals in large regions of urban and rural areas. The impact of this weak signal scenario can be seen in the TV antenna gain recommendations found in FCC report 05-199 "Study of Digital Television Field Strength Standards and Testing Procedures", December 9, 2005. Page 10 of this report highlights the recommendation of a 10 dB gain antenna at UHF, with the antenna positioned outdoors 30 feet above the ground. Indoor antenna placement is not recommended. For reference, a 10 dBi gain antenna at 550 MHz (middle of UHF TV frequency band) in a two-dimensional form factor would need to occupy an area that is approximately 450 sq. inches, i.e. about 20 times the area of the typical smartphone.

Along with achievable bandwidth and efficiency (gain), isolation is an important parameter that needs to be optimized for a multi-antenna system in a handset. Isolation or coupling can be defined as the level of power transmitted through a two-port network. In the case of a multi-antenna system integrated into a smartphone one port is the antenna of interest and the second port can be another antenna in the device. There are mainly two coupling mechanisms involved; conductive and

radiative. Conductive coupling is caused by currents induced by the antenna on the ground plane. Radiative coupling is due to the near fields generated by the antenna. The isolation that can be achieved is related to the separation distance between antennas in wavelengths as well as polarization state of one antenna in relation to the other antennas. As the frequency of operation increases, the wavelength decreases and the required separation distance for a specific isolation level decreases. Conversely, as the frequency of operation decreases additional separation distance will be required between antennas to achieve a comparable isolation.

As the isolation decreases between antennas in a multi-antenna system, the efficiency will decrease due to power being coupled from a transmitting antenna to one or multiple antennas in the device, resulting in absorbed power instead of radiated power. A second negative system level effect of reduced antenna isolation is increased interference or noise levels in receivers due to coupled signals from one antenna to another. A third issue related to poor isolation comes into play where MIMO or antenna diversity is applied; reduced antenna isolation between antennas in a MIMO or diversity system will result in reduced system performance. As isolation is reduced between two antennas the two antennas appear to operate as a single “antenna port”, eliminating the effectiveness of transmitting or receiving multiple data streams simultaneously in a MIMO system, for example.

Antenna and Radio Design Constraints

The physics of antenna design dictate that a low frequency antenna such as the antenna/antennas used for LTE Bands 5, 6, 8, 12, 13, 14, and 17 or an antenna for UHF TV reception be placed along one of the short dimensions of the smartphone to achieve optimal gain characteristics. This is due to the antenna requiring the longest extent of ground plane for best operation, with the ground plane being provided by the circuit board that houses the radios and other components. For this reason, the main and secondary cellular antennas used for 3G and 4G LTE operation need to be located along the short dimensions of the smartphone to optimize performance for low band LTE, with the main antenna positioned along one end of the smartphone and the secondary antenna positioned along the opposite edge. If UHF TV functionality is required in a smartphone, this phenomena of improved low frequency antenna operation with proper alignment of the antenna to the PCB points toward the concept of combining the TV functionality with either the main cellular or secondary cellular antenna.

There are several risks of combining a low frequency receive function such as TV reception with the main or secondary cellular antenna, and radio performance will degrade to some extent at all bands required of the antenna when implemented. When a single antenna is used to service two radios a switch or diplexer is required to connect the antenna to the two radio ports. The switch or diplexer will introduce 0.5 to 0.7 dB of insertion loss at both frequency bands that the antenna is tasked to service resulting in reduced SINR at both transmit and receive functions. Receiver

desense is a concern and needs to be addressed with filtering in the front-end module design to make sure that noise levels in the multiple receivers is not increased due to co-existence issues.

In addition to the combining losses from the switch or diplexer additional losses in the antenna will result from the requirement to extend the frequency bandwidth to accommodate the new frequency range. A review of a well-known theorem in electrical engineering, Fano's Gain Bandwidth theorem, will show that any increase in bandwidth from a load such as an antenna will result in an increase in the reflection coefficient that can be achieved from a loss-less matching circuit. What this means is that a higher mis-match loss will need to be accommodated in the main or secondary cellular antenna when the frequency range is extended to accommodate additional functionality, and this higher mis-match loss will result in reduced power entering the antenna for transmission or being received by the antenna. The components used in matching circuits to provide the additional required bandwidth have losses, and these losses will also decrease the gain of the antenna. This reduced antenna performance will occur at both the cellular frequencies and the new frequency range introduced into the antenna design.

Summary

As requirements increase to integrate additional radio functionality into smartphones radio system performance will be impacted due to interference between radio systems and coupling between antennas in the overall antenna system. An increase in size of the smartphone will help to mitigate this trend but there are practical limits to the acceptable size of a mobile device. Additional filtering will need to be designed into the RF front-end which will also degrade transmit and/or receive power levels at cellular and other frequency bands. Digital signal strength levels in the U.S. are marginal, such that consistent indoor reception will not be realized from the antenna gain that can be achieved at UHF frequencies when the antenna is integrated into a smartphone form factor. To add to this is also the integration of NFC antennas and wireless charging systems.

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